# A novel scheme for fast extraction of low energy beams from the ESR to the CRYRING

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The CRYRING@ESR facility [1] will provide the unique possibility for studying properties of low energy cooled heavy beams in the field of atomic and nuclear research within the FAIR project [2]. Heavy ion beams will be stored, cooled and decelerated to the energy of about 4 MeV/u in the ESR and then delivered to the CRYRING. Presently, there is no special kicker magnet which could be used for the fast extraction towards the CRYRING. However, a special distorted closed orbit has been suggested, applying it to the stored beam one can perform the fast extraction with the existing injection kicker magnet.

## Calculation

The beam from SIS18 is usually injected into the ESR on the orbit of $\Delta p/p \approx +1\%$, and then stored and cooled (solid black curve in Fig. 1). In order to keep the beam parallel to the electron beam in the cooler section, 4 horizontal correctors in 2 neighboring main dipole magnets are used. The ESR is equipped with one injection and two extraction septum magnets. The horizontal width of the beam pipe around the septums is 104 mm and in addition, there is the narrow knife of 17 mm width of each septum (see Fig. 1). The injection kicker magnet is placed after the first dipole downstream. The beam goes after the kick either to the northern extraction septum (towards the HITRAP) or to the wall (dotted black curve in Fig. 1). In order to extract the beam to the CRYRING, it is necessary to change the trajectory of the kicked beam, such that it avoids the knives of the septa but reaches the southern extraction septum. This orbit distortion has been performed with a special bumped closed orbit, which has been calculated using 8 horizontal correctors in 4 main dipoles (dashed black curve in Fig. 1). Applying the kick on the distorted orbit the beam can freely be extracted to the CRYRING (dotted-dashed red curve in Fig. 1).

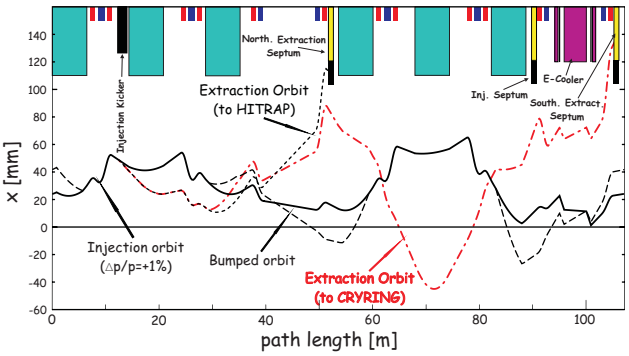


Figure 1: Calculated beam trajectories for one turn in the ESR. The injected stored orbit of $\Delta p/p = +1\%$ is indicated by the solid black curve. Its kicked orbit (extraction to HITRAP) is shown by the black dotted curve. The distorted bumped orbit is marked by the dashed black curve and its kicked orbit (extraction to CRYRING) is shown by the dotted-dashed red curve.

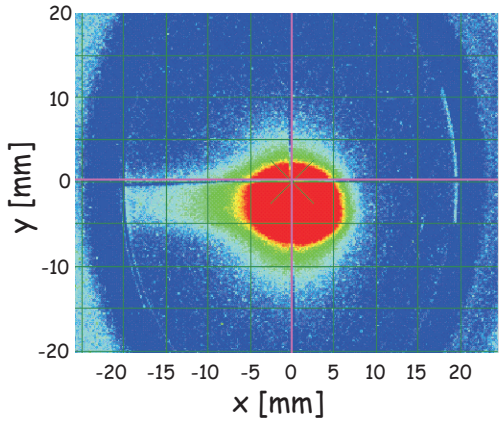


Figure 2: The extracted 100 MeV/u $^{58}Ni^{26+}$ beam directly after the extraction septum.

## Experiment

In August 2014, the calculations could be proven by experiments at the ESR. Firstly, the proposed extraction scheme was verified with 100-400 MeV/u proton and $^{58}Ni^{26+}$ beams. The extracted beam was measured directly after the septum using a fluorescent screen (see Fig. 2). Later, a $^{14}N^{7+}$ beam at 30 MeV/u was injected, stored and stepwise decelerated iteratively to the final energy of 4 MeV/u ($B\rho = 0.58$ Tm), the lowest possible magnetic rigidity from the ESR to the CRYRING. At each energy, the beam was successfully extracted, changing only the kick angle of the injection kicker by several tenths of a milliradian. The distortion orbit was unchanged. Despite the lack of experimental time, it could be managed to transport the extracted 4 MeV/u ion beam over a length of 20 m towards the CRYRING for the first time.

## References

[1] CRYRING@ESR, A study group report
https://www.gsi.de/fileadmin/SPARC/documents/Cryring/ReportCryring_40ESR.PDF

[2] http://www.fair-center.eu/

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